MANURES AND FERTILIZERS FOR TRUCK CROPS

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BULLETIN

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MANURES AND FERTILIZERS FOR TRUCK CROPS

J. H. GOURLEY AND ROY MAGRUDER

The growing of vegetables is a specialized industry, whether it be in the open or under glass. It is a long step from the vegetable garden or "patch" of the pioneer to the modern developments in market-gardening and truck-growing. For greatest returns careful planning is required. This applies to the city, town, or suburban garden; to the intensely cultivated areas in the vicinity of the cities known as market gardens; and to the more remote sections that produce special crops to be shipped some distance to the consuming centers. Varieties, cultural methods, means of controlling or avoiding injurious insects and diseases, and marketing methods, all call for an increasing knowledge of gardening procedure.

A new problem is being created as cities are rapidly encroaching on the suburban districts where market gardening has long been established and where the annual additions of fertilizing substances have resulted in a highly productive soil. Also, in some places, insect or disease infestation or infection is causing the growers to look elsewhere for land on which to grow the vegetable crops. These problems at once raise the question, what methods of culture and fertilization are necessary or adequate to successfully grow these crops on a new soil or at least on one which has had good farm practice only and not the annual addition of from 20 to 40 tons of manure as well as some chemical fertilizers. With the growing scarcity and increasing price of manures, can the grower look forward to intensive garden culture without manures at all, or to what extent can they be eliminated? The investigation reported in this bulletin is an attempt to answer these questions, at least in part, and as the work is continued from year to year the findings should be of increasing value. But now, after nine years, certain phases of the problem have advanced sufficiently to warrant some conclusions for the soils under consideration.

HISTORY OF WORK

In the fall of 1914 a 10-acre tract of land was purchased as a part of the Washington County Experiment Farm. This tract lies on what may be termed the second terrace of the second bottom of the Muskingum River, about 4½ miles northwest from Marietta, on the east side of the river and on the Muskingum Pike.

The organization during this 9-year period has provided that the Department of Farm Management administer the details of the farm. The experiments themselves are initiated by the chief of the Department of Horticulture at the central Experiment Station in consultation with the chief of the Department of Farm Management. The results of the experiments and their interpretation are prepared for publication by the Horticultural Department; and thus the county farm contributes to the research work of the State at large as well as to the county, altho its chief object is to solve the problems peculiar to the county in which it is established.

The farm itself had been a part of a general farm, raising corn, wheat, and hay (no clover) until about 1908. It was then rented to gardeners for three years, but the soil appeared to be too infertile, and they fared poorly. The tract was then sold for $5,500 and it was used for truck farming for the next four years, but the results were again unsatisfactory and the farm and holdings were sold for $8,000 in 1914 to the county for use of the Experiment Station. Under good cultural methods, the yields have steadily increased. The gross returns have been as follows: 1915, $600; 1916, $1,600; 1917, $2,000; 1918, $3,900; 1919, $3,800; 1920, $4,300; 1921, $2,500; 1922, $2,228.06; and 1923, $3,109.13. In addition to the general cropping and miscellaneous experiments there are 128 fortieth-acre plots on which are studied experimentally the effects of manures, fertilizers, lime, and cover crops.

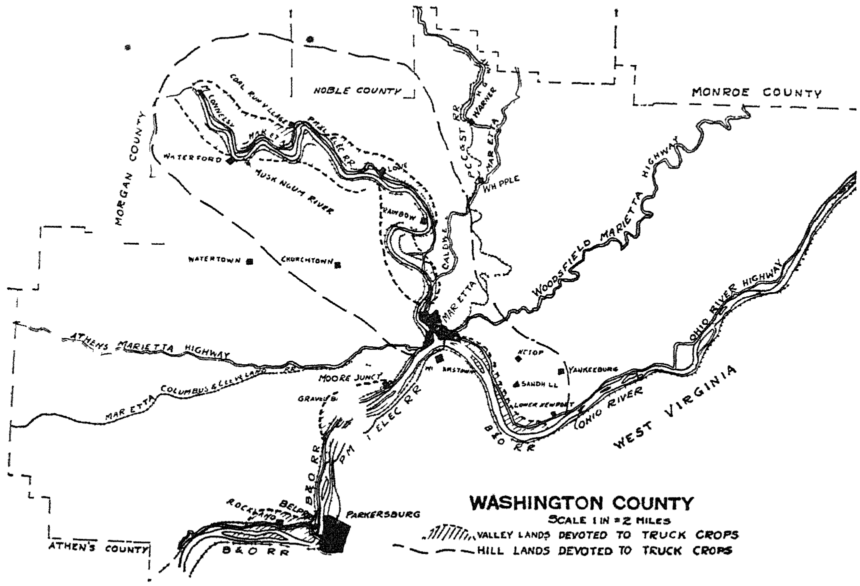
It can not be too strongly emphasized that an experiment farm should not be operated with a view of making it "pay", for in so doing the principal object of the effort may be lost, or, at least, there would be a tendency to mold the work with an aim to make a good financial showing. Fortunately, this view is shared and appreciated by the truck-growers of the Marietta district who have whole-heartedly supported the work. This is mentioned so that other districts that may desire similar experiment farms in the future will not be misled by the returns that have been secured from this farm in addition to its experimental value.

Note: The foreman of the truck farm, O N Riley, has been in constant service since November of 1914, and much of the success of this work is due to his loyal and efficient management.

THE MARIETTA DISTRICT

The Marietta truck district has been developing as such for the last twenty-five years. Beginning in the vicinity of Marietta the district has gradually extended up and down the Ohio Valley, up both sides of the Muskingum River where there are terraces of suitable soil, and more lately into the hill land.

The average rainfall at Marietta for six years, 1916-1921, was 40.95 inches and was well distributed thru the growing season.



Outline map of the Marietta trucking district, showing the comparative area of valley and hill lands devoted to growing truck crops

This is primarily an early trucking district. Its aim is to produce the bulk of the crops before home-grown produce appears in the middle-west markets. It fills in the period between the close of the southern and the opening of the northern shipping seasons. As soon as locally-grown produce appears on the market, prices begin to drop, hence the earliest crops usually bring the best prices. A few days delay in maturity may make the difference between profit and loss for the season.

LOCATION AND SOIL

The Muskingum Valley is half a mile to a mile in width, expanding to several miles near the mouth, and the Ohio River is bordered by a belt of bottom and terrace land half a mile or more in width, all of which furnishes an area of sheltered alluvium and terrace land which has been found to be especially adapted to the growing of truck crops.*

Most of the hill soil is yellow, altho some of the fields are of a dark brick-red color. These soils are naturally later in maturing their crop but the growers find that by giving the truck crops especial care they are more profitable than farm crops and the area of hill land devoted to truck crops is increasing rapidly. The proximity to loading points and good roads seems to be the limiting factor in the extension of this area.

The river valley or bottom lands contain a wide variety of soil types including sand, gravel, loam, and clay and various combinations of these. It is not uncommon to find four or five different types of soil on a ten-acre tract. It is often impossible, for this reason, to select the type of soil best suited to the crop to be grown and as a general rule rotations are followed regardless of the soil type.

The Baltimore & Ohio Railroad and the Monongahela Electric Traction line provide the transportation thru the valley. Cars are loaded at Waterford, Lowell, Rainbow, and Marietta, Ohio, and Williamstown, West Virginia. The electric line has special freight service during the shipping season and, at numerous sidings up the Muskingum Valley, receives produce which is moved to Williamstown, W. Virginia, where it is loaded into refrigerator cars for its final destination.

The accompanying map shows the location of the valley and hill lands and the respective loading points.

THE MARIETTA TRUCK GROWERS' ASSOCIATION

The Marietta Truck Growers' Association is very largely responsible for the success and rapid growth of the industry in this section. It was largely their efforts at improving the quality of the pack and properly marketing it that brought the produce into favor on the market and assured success.

The association started in 1907 with a few dozen growers. By 1910 it was well organized, and its 65 members decided to sell collectively. They made a contract to sell thru the Crutchfield and Woolfolk Co. of Pittsburgh, which later became associated with the American Fruit Growers, Incorporated. In 1915 they registered a trademark and now everything is shipped under the "Pioneer Brand" in uniform sized packages and grades. Grading is done by

*Ohio Agr. Exp. Sta. Bul. 326, p. 418.

the individual grower, but it is subject to inspection before loading in the car. Any lot falling below grade is placed in a special pool and sold on its merits. The association now has 550 members and ships about 75 percent of the tonnage produced in the section.

In 1911 the association shipped 4,129 crates of cabbage and 44,841 baskets of tomatoes. In 1922 it handled 66,213 crates of cabbage and 185,869 pounds in bulk and 287,297 baskets of tomatoes. It required 825 cars to move the 1922 crop. The gross receipts rose from $35,000 in 1910, to $346,620.95 in 1922. In 1923 the association shipped the following quantities of the principal crops:

Tomatoes	286,843 baskets
Cucumbers	8,643 hampers
Cabbage	74,043 crates and 90,323 pounds bulk
Corn	10,747 hampers and 251 sacks

About 25 percent added to these figures will give the total production of the section.

CHIEF CROPS AND VARIETIES OF DISTRICT

The chief crops are cabbage, tomatoes, cucumbers, and sweet corn, altho a number of other crops, such as peppers, peas, turnips, beans, onions, early potatoes, and egg plants, are grown in a smaller way. Tomatoes are shipped in 12-quart Climax baskets holding about 20 pounds; cucumbers in 1 and 1½ bushel hampers; cabbage in crates holding about 100 pounds (16 by 16 by 28 inches); and corn in 1 and 1½ bushel hampers.

The varieties most commonly grown at the present time are of the earlier sorts, since this is primarily an *early* trucking district. The following prevail: tomatoes—Bonny Best, some John Baer, Globe, Early Detroit, and Chalks Early Jewel; Cabbage—Copenhagen Market and a little Jersey Wakefield; Cucumbers—Early White Spine and some Davis Perfect; Corn—Livingston's Early Sugar and a little Adams Early.

PLANTING DISTANCES

Cabbage in rows 34-36 inches apart with plants 14-17 inches in rows; sweet corn in rows 30-36 inches, hills 20-24 inches apart, and 2-3 plants to the hill; cucumber hills 4 by 3 or 4 feet and thinned to 2 or 3 plants per hill; tomatoes in rows 4 feet apart with plants 2 feet in the row and trained to a single stem on stakes.

Planting distances on the experiment farm differ from these because of the size of the plots. It was necessary to modify the usual distance so as to waste no space and yet secure the maximum number of plants that would make a normal growth. Tomato rows are 50 inches apart and the plants, 34 inches in the row, are tied to stakes and pruned to a single stem. Cabbage plants are set 36 by 17 inches. Cukes are planted in hills 50 by 34 inches and thinned to 3 plants in a hill. Corn is planted in hills 36 by 34 inches and thinned to three stalks per hill.

SEEDAGE AND HARVEST

Seed for cabbage plants is sown from the first of January to the middle of February in hotbeds or small greenhouses. Some of the growers sow thinly and do not transplant, while others transplant into hotbeds or cold frames, setting the plants about 1½ inches apart each way. In the last few years some of the growers have started their cabbage plants in the fall and wintered them in protected cold frames. The plants are set in the field from April 15 to 20, depending upon the season.

Most of the growers use a one-horse cultivator and go over the fields at least once a week.

Harvesting cabbage begins about June 15 and lasts until the first of August. Most of the growers use a low, wide-wheeled, one-horse cart that straddles two rows, in hauling the cabbage from the fields. Two or three cutters usually work to each cart. The cart is easily emptied by removing the end gate. Packing is done by the individual grower at his barn or at the edge of the field where he provides protection from the hot sun until the truck delivers the crates to the car for shipping.

Tomato seed is usually sown from the first to the middle of March and the plants are transplanted into cold frames or hotbeds. Most of the plants are only shifted once, being set 3 by 4 or 4 by 4 inches. They are set in the field from May 5 to 20, and harvest begins about June 25. Some haul the tomatoes to a shed for packing while others sort, wipe, and pack on benches at the field.

Cucumbers and sweet corn are usually planted about the first of May or as soon as danger from frost is past. Harvest begins about the middle of July.

INSECTS AND DISEASES

The cabbage is so early that the cabbage worms do very little damage. A dust composed of 20 parts land plaster or gypsum and 1 part of calcium arsenate is used on the cucumbers to control the cucumber beetles. The plants are kept covered with this material from the time they come up until they start to run.

In hot, dry seasons cabbage yellows and tomato wilt cause some loss but neither has become serious enough to compel the growing of resistant varieties. In the majority of seasons the crop matures before weather conditions are favorable for these diseases.

EXPERIMENTAL WORK AND RESULTS

APPLICATION OF FERTILIZERS

On the truck experiment farm chemical fertilizers are broadcast by hand a short time before planting. The ground limestone is usually applied after plowing and is worked in when preparing the soil for planting, altho part of it is now applied to the rye cover crop in the fall. On the nitrate plots where two applications are made, the first half is drilled on before planting and the second half applied broadcast by hand or drilled with a hand drill along the rows about two or three weeks after the plants are set in the field. Manure is spread and plowed under in the spring. The straw mulch is applied as soon as the cucumbers and sweet corn are large enough to mark the rows plainly.

Straw mulch left, untreated plot right.
Showing the detrimental effect of the fresh straw mulch on cabbage

COVER CROPS

Cowpeas are sown as soon as the cabbage is cut, usually from July 15 to August 1. They are drilled between the rows of tomatoes and corn at the same time, using about 2 bushels of seed to the acre. Rye is grown as a cover crop on the cucumber land

and is sown at the rate of 4 to 6 pecks per acre after the picking season is over. The growing season is sufficiently long to produce a good heavy growth of both crops, which cover the soil thru the winter and make a good supply of organic matter to be turned under in the spring. On Series B the check plots have maintained their original production; while on Series A, where two tons of ground limestone per acre is used every two years in addition to the cover crops, the production of the check plots has been slightly increased. This indicates the value of leguminous cover crops and ground limestone as a basic soil treatment.

THE PLAN OF EXPERIMENTS

Two series of experiments are included in this report, designated as Series A and B. Series A is styled a soil fertility experiment and Series B a soil improvement experiment, the difference being only that certain plots of the first series are untreated except with lime and cover crop, while certain ones of the second series that serve as control plots receive neither lime, manures, nor chemicals but receive only such enrichment as accrues from the cover crop grown after the crop is removed. The chart on page 127 gives the plans of this work; see also map page 121.

GENERAL RESULTS

DISCREPANCIES AND INEQUALITIES

When a piece of land is first used for experimental purposes it is likely to be discovered that inequalities exist in it, that is, different portions of a field which seems to be quite uniform will produce slightly or widely different results from identical treatments. This is due to either or both of two conditions: first, a difference in the native or natural fertility of the soil, that is, a variableness thruout the field even tho it appears uniform; second, lack of uniform cropping and treatment in former years. Certain portions may have had heavier or more frequent fertilizing, manuring, or liming than others, or conversely more exhaustive cropping. The differences due to the latter of these two causes are likely to disappear or become "ironed out" as the work proceeds. The former will persist.

METHOD OF CALCULATIONS

The Ohio Experiment Station has recognized these exigencies from the first and attempted to overcome them by the use of many untreated plots, rather than a single one, against which to check the benefits or increases derived from the several treatments.

Washington County Experiment Farm, Truck Crops Division; Plan of experiments in the use of fertilizers, manures, and cover crops. Fertilizers and manures per acre. Plots 1-40 acre

SERIES A SOIL FERTILITY PLOTS	SERIES B SOIL IMPROVEMENT PLOTS
1 Unfertilized	21 Unfertilized. Mulched with straw
2 Shed manure, 16 tons Acid phosphate, 400 lb.	22 Unfertilized
3 Shed manure, 16 tons	23 Manure, 16 tons Acid phosphate, 400 lb. Nitrate soda, 160 lb.; mur. potash, 50 lb.
4 Unfertilized	24 Manure, 16 tons
5 City manure, 16 tons	25 Manure, 16 tons Ground limestone, 1 ton
6 Acid phosphate, 800 lb. Nitrate of soda, 320 lb. Muriate potash, 100 lb.	26 Manure, 16 tons; ground limestone, 1 ton Acid phosphate, 400 lb. Nitrate soda, 160 lb.
7 Unfertilized	27 Manure, 16 tons
8 Acid phosphate, 400 lb. Nitrate soda, 160 lb. Muriate potash, 50 lb.	28 Manure, 16 tons Acid phosphate, 400 lb. Ground limestone, 1 ton
9 Acid phosphate, 400 lb. Nitrate soda, 160 lb.	29 Unfertilized
10 Unfertilized	30 Acid phosphate, 400 lb. Nitrate of soda, 160 lb. Muriate potash, 50 lb.
11 Acid phosphate, 400 lb.	31 Acid phosphate, 400 lb. Nit. soda, 160 lb.; mur. potash, 50 lb. Ground limestone, 1 ton
12 Nitrate soda, 80 lb. Sulphate ammonia, 65 lb.	32 Unfertilized
13 Unfertilized	33 Ground limestone, 1 ton
14 Nitrate soda, 160 lb. (In two applications)	34 Acid phosphate, 400 lb. Nitrate soda, 160 lb. Ground limestone, 1 ton
15 Nitrate soda, 160 lb. (In one application)	35 Unfertilized
16 Unfertilized	36 Acid phosphate, 400 lb. Ground limestone, 1 ton

Plots 1 to 16 are cross-dressed every second season with finely-ground raw limestone, 2 tons per acre, spread over fertilized and unfertilized land alike. They have also received a cover crop of cowpeas after sweet corn, cabbage, and tomatoes, and of rye after cucumbers.

Plots 22 to 28, inclusive, receive a cover crop of rye after each crop and Plots 29 to 36 receive a cover crop of cowpeas after each crop except cucumbers, which are followed by a rye cover crop.

Furthermore, the treated plots are compared with the untreated ones adjacent to them rather than with the average yield or response of all the untreated plots.

For instance: when every third plot is untreated as in the first (A) series of this experiment, the increase from the treatment is calculated in the following way, a method originally used by C. E. Thorne of this Station:

		Yield of cabbage
Plot 1	Check	17,573
Plot 2	Shed manure 16 tons Acid phosphate 400 lbs.	22,513
Plot 3	Shed manure 16 tons	21,888
Plot 4	Check	18,191

Subtract the smaller from the larger of the two checks; divide this difference by three and add the value received to the smaller check (Plot 1) to get the probable yield of the adjacent plot (Plot 2), had it been untreated; and subtract it from the larger check plot (Plot 4) to get the probable yield of its adjacent plot (Plot 3). The probable or calculated yield is the theoretical yield which a plot would produce if it were not treated.

The increase or decrease due to treatment is then found by subtracting the probable yield from the actual yield as follows:

	Calculated yield	Actual yield	Increase due to treatment
Plot 1	17,573 (check)		
2	17,779	22,513	4,734
3	17,985	21,888	3,903
4	18,191 (check)		

Due to the arrangement of the check plots in Series B, a different method is used in calculating the probable yield. The actual yield of Plot 22 is assumed to be the probable yield of Plot 21 had it not been treated, and the actual yield of Plot 35 is similarly assumed to be the probable yield of Plot 36. The average yield of Plots 22 and 29 is used as the probable yield of the intervening plots. The method used in Series A is followed for Plots 30, 31, 33, and 34. In calculating the net profits the same methods are used as in determining the increases in yield.

DISCUSSION OF THE TWO SERIES

The yield on the check plots in the two series of this experiment are scarcely comparable. Those in Series A, which are limed, are higher in yield than those of Series B, which are not limed, and hence the increases in the latter series are much greater altho the actual yields of similarly treated plots in the two are not greatly different as can be seen in Tables III and V. This precludes a close comparison of the two series and hence they are for the most part discussed separately.

THE UNTREATED PLOTS

An examination of Table III discloses a consistency in behavior of the untreated plots (1, 4, 7, 10, 13, and 16), but shows that the land is less fertile to the west, the last plot (Plot 16) being lower in yield than the first by about 12.7 percent for all crops in an 8-year average. While all treatments have given yields higher than the check plots, except Plot 21, yet in some cases the cost of the treatment was greater than the value of the increase secured.

By averaging the yields of these plots it appears that the field as a whole would produce the following yields per acre if no fertility had been added, which, of course, would not represent a likely practice in any section of Ohio.

9-YEAR AVERAGE YIELDS OF CHECK PLOTS IN SERIES A (Limed) AND SERIES B (Unlimed)

Crop	Pounds per acre		Tons per acre	
	Series A	Series B	Series A	Series B
Corn	7,296	6,419	3.6	3.2
Cucumbers	16,654	13,231	8.3	6.6
Cabbage	17,264	15,075	8.6	7.5
Tomatoes	9,171	6,549	4.6	3.3

The check plots in Series A, like the treated plots in the same series, receive 2 tons of ground limestone biennially. Those in Series B (Plots 22, 29, 32, and 35) receive no lime, but like those in Series A, have a cover crop plowed in each year.

In considering these yields it should be remembered that the land was in a low state of fertility when the experiments were started and that neither manure nor fertilizer has been added to the check plots since. Further, the crops are grown for an early market, hence, in the main, the yields are somewhat lighter than would be true of late-maturing varieties of vegetables.

While seasonal variation and occasional outbreaks of insects and diseases have caused fluctuations in yield, the general tendency of the check plots has been to maintain the yields, or increase them. An exception to this has been obtained with the tomato crop due to increased losses from disease.

INCREASED YIELDS FROM MANURING

Market and truck gardeners use large quantities of manure, ranging from about 15 tons to 40 tons per acre annually, or practically as much as they can secure. No experiment is needed to demonstrate that manure will maintain the fertility of the land or that it will greatly increase the yields of almost any crop, whether of vegetables, flowers, farm crops, or trees. But the scarcity and high price of animal manures is rapidly becoming a serious problem to the gardener; therefore, field experiments to ascertain to what degree and for what crops they may be profitably replaced by chemical fertilizers and green manures, will be of increasing value to the trucker.

That manures contain a proportionately smaller amount of the element phosphorus than of nitrogen or potassium (potash) is well known and hence it is not surprising to find that on some crops in this and other experiments the addition of phosphorus to manures is producing higher yields than manure alone, altho it has not been profitable in all cases.

Wherever manure is used in this experiment, it is applied at the rate of 16 tons to the acre annually, a moderate application for land devoted entirely to vegetable production. In 9 of the 22 treated plots manure is used either alone or in combination with lime, chemicals, or both.*

In these calculations a ton of manure which has been exposed to the weather is estimated to contain 8 pounds of nitrogen, 4 of phosphoric acid, and 8 of potash (K_2O) and has cost \$3.75 spread on the land. The same amount of fertility can be purchased in the form of nitrate of soda, acid phosphate, and muriate of potash for \$2.28 spread on the land. Therefore, it is costing more to buy the fertility in the manures and it is well known that the elements of fertility in manure are not so available as in the soluble salts used in chemical fertilizers. It would seem, then, that the manure must possess some value in addition to its fertility if it is to be used economically under the conditions of these experiments.

By referring to Tables I and III, Plots 3, 5, 24, and 27, it will be seen that manure used alone or with a basic treatment of limestone, has given an increase on all crops. But when the cost of the manure (\$3.75 per ton spread on the land) is deducted from the value of the increase, as seen in Tables II and IV, there is a net

*In the future one plot will receive 20 tons of manure, and one 8 tons together with lime and a complete fertilizer. The original plan called for protected and exposed manure, but, it later became necessary to buy all the manure from a military post This manure had been exposed to weathering average loss per year in all cases with corn, a poor showing in Plots 3 and 5 with cucumbers, but a profit, often a big profit, with the other crops, particularly in Series B, where the unlimed check plots are lower and the increases are consequently much higher than in Series A.

It is plain, then, that sweet corn does not show a profit on this soil for 16 tons of manure at $3.75 a ton used year after year.

The largest net return from this treatment is found with tomatoes. This has usually been a profitable crop in the Marietta district, and an average net profit of $52.68 has been secured from the use of 16 tons of manure on Plots 3 and 5, and in Series B of $123.27 on Plots 24 and 27.

Cabbage shows a small profit on Plots 3 and 5 and a large profit in the other series, $94.31.

A further study of the manurial treatments in Series B throws some light on this matter. The plots in this series cannot be directly compared with those in Series A because the increases are calculated on a different basis (see treatment of check plots) but an examination of Tables I and III shows that the actual yields are similar and that the one series would probably corroborate the other if a basis of comparison were available.

In this series manure alone (Plots 24 and 27) has given the following profit, or loss (—), over the untreated plots:

Corn	Cucumbers	Cabbage	Tomatoes
$—18.15	$57.77	$90.28	$123.27

When a comparison is made between Plot 33 receiving an annual treatment of 1 ton of ground limestone and Plot 25 receiving in addition to the limestone, 16 tons of manure, we see again that manure has been quite profitable in all cases except with corn.

Plot	Corn	Cucumbers	Cabbage	Tomatoes
25	$—19.90	$73.25	$102.38	$137.26
33	10.74	4.43	61.74	17.05
Gain from manure....	—30.64	68.82	40.64	120.21

When 16 tons of manure is used in addition to a treatment of 400 pounds of acid phosphate, 160 pounds nitrate of soda, and 50 pounds muriate of potash (Plots 23 and 30) the cost of treatment is increased from $10.30 to $70.30 per acre, giving a profit with cabbage and tomatoes but a serious loss with corn and cucumbers, as seen by the following:

Plot	Corn	Cucumbers	Cabbage	Tomatoes
23	$—35.44	$ 34.85	$128.22	$128.32
30	10.76	81.74	101.32	73.70
Gain or loss from manure	—46.20	—46.89	26.90	54.62

Again, when manure is added to a treatment of 400 pounds of acid phosphate and 1 ton of ground limestone at an increased cost of from $9 to $69 (Plots 28 and 36), a treatment which may practically accord with the practice of many growers, the figures show a substantially increased profit in all cases except with corn.

Plot	Corn	Cucumbers	Cabbage	Tomatoes
28	$—16.50	$90.46	$96.28	$140.26
36	— 3.90	2.71	64.40	48.47
Gain or loss from manure	—12.60	87.75	31.88	91.79

Lastly, there is a comparison of the value of 16 tons of manure added to a treatment of 400 pounds acid phosphate, 160 pounds nitrate of soda, and 1 ton of ground limestone (Plots 26 and 34). This treatment is the most costly in the two series, raising the cost of the larger application from $13.80 to $73.80 and yet showing a profit. This combination carries about 153 pounds of nitrogen or nearly what would be carried in 1,000 pounds of nitrate of soda; as much phosphoric acid as is found in 800 pounds of 16 percent acid phosphate, and as much potash as is carried in 360 pounds of muriate of potash—a total of more than a ton of these chemicals. Except for corn, the outcome would warrant the expenditure.

Plot	Corn	Cucumbers	Cabbage	Tomatoes
26	$—27.70	$123.61	$145.98	$124.30
34	11.26	42.79	134.22	91.90
Gain or loss from manure	—38.96	80.82	11.76	32.40

MANURE AND CHEMICALS

The question then arises as to what response will be secured with these crops if the manure is treated with acid phosphate in order more nearly to balance it as a fertilizer. It is a common practice to add 40 pounds of acid phosphate to each ton of manure, altho in this case 25 pounds was used.

An analysis of the figures shows that in Series A the addition of phosphate to manure produces no response in sweet corn and only adds to the deficit incurred by the use of the manure. In Series B there is a slight increase and the deficit is somewhat reduced. These results emphasize the general experience in this work that sweet corn has not been consistent in its behavior and rarely has given a profit from the treatments so far employed.

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*Cost of soil treatments and value of produce·
The calculations of the value of the increased yields secured in these experiments are based on the following figures, which are the nearest whole figures of the actual cost for the eight-year period, altho the different items have varied somewhat from year to year

Limestone $5 00 a ton, manure $3 75 straw at $12 00 a ton, 16 percent acid phosphate, 1 cent a pound, and nitrate of soda and muriate of potash each 3 cents a pound, all spread on the land

In the computations sweet corn is valued at 2 cents, cucumbers at 1½ cents, cabbage at 2 cents, and tomatoes at 3½ cents a pound

Whether a change in treatments or in the system whereby more plants can be grown per acre will give a satisfactory response in a rotation such as is being followed remains to be seen.

Untreated plot on left compared with Plot 23, receiving 16 tons manure, 400 pounds acid phosphate, 160 pounds nitrate of soda, and 50 pounds muriate of potash. Note the vigorous tomato vines on treated plot

Cucumbers have done little better than the corn in this regard in Series A, but in Series B there is an increase in yield and in net returns as a result of the added material. Until the work has proceeded further, the latter finding may be advised and some additional phosphorus added to the manure when the crop is planted.

Cabbage, like cucumbers, has responded markedly to the manurial treatments ranging from 20 to 22 thousand pounds total yield in Series A and 23 thousand in Series B, but with no marked increase from the addition of the phosphorus. As with cucumbers the results are inconsistent in the two series, a slight loss occurring in Series B, as indicated when Plot 25 is compared with 28.

Tomatoes show an increase and a profit from the use of phosphorus. In Series A the gain is $28.69 and in Series B, $3. It seems conclusive that the practice of using phosphated manure is profitable with tomatoes.

INCREASES AND PROFIT OR LOSS (—) SECURED FROM THE ADDITION OF 400 POUNDS ACID PHOSPHATE TO 16 TONS MANURE. 8-YEAR AVERAGE

Plot	Corn		Cucumbers		Cabbage		Tomatoes	
	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars
Series A								
Average 3 and 5.	705	—45.89	3,711	—4.32	3,589	11.78	3,219	52.63
2.......	473	—54.54	4,036	—3.46	4,847	32.94	4,153	81.37
Increase..........	—232	....	325	....	1,258	21.16	934	28.69
Series B								
25........... .. .	2,255	—19.90	9,217	73.25	8,369	102.38	5,779	137.26
28	2,625	—16.50	10,631	90.46	8,264	96.28	5,979	140.26
	370	....	1,414	17.21	—105	—6.10	200	3.00

MANURE VS. CHEMICAL FERTILIZERS

The next question of importance is the comparative value of manure and chemical fertilizers in the growing of truck crops. Unfortunately, the amount of nitrogen, phosphoric acid, and potash which is contained in the manure applications is not duplicated in the amount of "chemicals" used in this experiment, with the exception of phosphorus, as shown by the following table:

Plot		Nitrogen Pounds	Phosphoric acid Pounds	Potash Pounds
6	Double chemicals	50	128	50
3	16 tons manure	128	64	128

But despite the fact that less than half the amount of nitrogen and potash is used in the "double chemicals" plot, the yield is greater than where the manure was used in either Plot 3 or 5, and it is nearly equal to the phosphated-manure plot. When the amount of chemicals is cut in half as in Plot 8 the total average increase of all the crops decreases by about a ton and a half, indicating that 610 pounds of a 4-10-4 fertilizer is too small an amount for the soil in question. This work is of much economic importance as it answers the question whether the truck gardeners in the Marietta section (and perhaps those on many other soils) can expect to grow satisfactory crops without the use of manure, if that becomes necessary.

When it is realized that an annual application of 1,220 pounds of a 4-10-4 fertilizer, together with cover crops, has equalled or surpassed the results secured from 16 tons of manure and that the net returns on the four crops are more than double over a period of eight years, the case is encouraging from the truckers' standpoint. It should not be overlooked, however, that on some soils it may first be necessary to incorporate a certain amount (variable with different soils) of organic matter in the soil before maximum returns can be secured from chemical fertilizers. The function of this decaying material may be to render the soil more friable and loose, or to provide an abundant soil flora, or both. It is not necessarily true, however, that a relatively unproductive soil will require manures in order to secure good results as is indicated by the striking response secured in these experiments. Not only is manure becoming scarcer and higher priced but it introduces and perhaps fosters many of the serious disease problems of the gardener. Furthermore, the manured plots are slower in maturing than those treated with chemicals, which is of the greatest importance in a section where earliness is the key to success.

INCREASES OF MANURE AND CHEMICALS OVER THE CHECK PLOTS, SERIES A, 8-YEAR AVERAGE

Plot	Treatment per acre	Corn	Cukes	Cabbage	Tomatoes	Net profit on four crops
		Lb.	*Lb.*	*Lb.*	*Lb.*	*Dollars*
2	Shed manure 16 tons; Acid phosphate, 400 lb.	473	4,036	4,847	4,153	56.31
3-5	Manure, 16 tons	705	3,711	3,589	3,219	14.24
6	Acid phosphate, 800 lb.; Nitrate soda, 320 lb.; Muriate potash, 100 lb.	884	3,669	4,892	3,422	207.93
8	Acid phosphate, 400 lb.; Nitrate soda, 160 lb.; Muriate potash, 50 lb.	628	3,256	3,489	1,848	154.65

Referring now to Series B where, as before, a direct comparison with the results in Series A cannot be made, we find the general conclusions drawn from Plots 2, 3, 5, and 6 can be substantiated.

Plots 24 and 27 receive like treatments, 16 tons of manure without any other basic treatment except cover crops. Plot 30 is treated with 610 pounds of a 4-10-4 fertilizer, which is not comparable, however, to Plots 8, 3, and 5. The average of the manured plots is much higher in actual yield and gain in yield over the check plots than Plot 30, but, as in other cases cited, the cost of treatment is such as to show a financial loss from the manure as compared with the fertilizer treatment, except in the case of tomatoes.

Plot	Corn	Cucumbers	Cabbage	Tomatoes
24 and 27 (average)	$—18.15	$ 57.77	$ 90.28	$123.27
30	10.76	81.74	101.32	73.70
Gain or loss (—) due to manure...	—28.91	—23.97	— 11.04	49.57

When the same comparison is made, except the addition of lime to both the manure and fertilizer combination, there is a gain in yield with all crops from the manurial treatment, but a financial loss with both corn and cabbage, as was true where no lime was used, and a gain with cucumbers and a substantial gain with tomatoes.

Plot	Corn	Cucumbers	Cabbage	Tomatoes
25	$—19.90	$73.25	$ 102.38	$137.26
31	9.94	70.99	140.30	70.10
Gain or loss (—) from manure over chemicals...	—29.84	2.26	— 37.92	67.16

Plots 25 and 36 give opportunity to compare a treatment of manure and limestone with 400 pounds of acid phosphate and limestone. As might be expected on this relatively infertile soil the use of manure has proved decidedly more profitable in all cases except with corn. Tomatoes and cucumbers have given the largest profit in this pair of treatments, cabbage about half as much, and corn has failed to show a profit from either treatment.

Plot	Corn	Cucumbers	Cabbage	Tomatoes
25	$—19.90	$73.25	$102.38	$137.26
36	— 3.90	2.71	64.40	48.47
Gain or loss (—) from manure over acid phosphate........	—16.00	70.54	37.98	88.79

NITROGEN ALONE IS NOT SUFFICIENT FOR MAXIMUM PRODUCTION OF THE CROPS STUDIED

Now if we examine the increase secured by the use of 160 pounds of nitrate of soda alone or its equivalent, we find that the yield drops down very materially. The increase with corn and tomatoes is slight, while with cucumbers and cabbage it is considerable; but unquestionably the application is far below the requirements of these crops. However, it again strikingly illustrates the fact that it is the crop rather than the soil that requires treatment.

INCREASE AND NET PROFIT FROM NITROGEN

Plot	Treatment per acre	Corn		Cucumbers		Cabbage		Tomatoes	
		Increase	Net profit	Increase	Net profit	Increase	Net profit	Increase	Net profit
		Lb.		*Lb.*		*Lb.*		*Lb.*	
15	160 lb. nitrate of soda in 1 application............	296	$1.13	1,952	$24.48	2,263	$40.47	184	$1.64
14	160 lb. nitrate of soda in 2 applications...........	217	—.47	1,289	14.54	1,772	30.63	55	—2.88
12	80 lb. nitrate of soda and 65 lb. sulphate ammonia	213	.08	1,529	18.58	1,435	24.35	185	2.14

If the value of nitrate alone be approached from another angle, as shown in Plots 9 and 11, we can subtract the results secured from land which receives 400 pounds of acid phosphate from those from land receiving 160 pounds of nitrate of soda in addition to the phosphate. This analysis shows net profits similar to those obtained in Plot 15 with the exception of the tomato crop, in which they are greater.

Plot	Corn	Cucumbers	Cabbage	Tomatoes
9	$7.38	$45.04	$61.61	$65.63
11	5.53	22.99	30.60	51.11
Increase from nitrate of soda....	1.85	22.05	31.01	14.52

In both of the preceding tables it is clear that 160 pounds of nitrate of soda used on land that receives a basic treatment of 2 tons of limestone biennially gives a large return on cabbage and cucumbers, but gives a relatively low return on corn and tomatoes. This amount of fertilizer seems very low and yet it has yielded a surprisingly good net return with cabbage. However, it cannot be considered satisfactory because of the still higher net returns from other treatments, as shown in Tables IV and VI.

In series B similarly the effect of adding or dropping out the nitrate of soda can be calculated in two sets of plots. Plot 26 receives manure, limestone, acid phosphate, and nitrate of soda; and Plot 28 receives the same treatment less the 160 pounds of nitrate. It is not quite accurate to subtract the results of the latter from the former to secure the effect of the nitrate, but this method of calculation gives an indication of its effect and the test was laid out with this point in view:

Plot	Corn		Cucumbers		Cabbage		Tomatoes	
	Increase	Net profit	Increase	Net profit	Increase	Net profit	Increase	Net profit
	Lb.		*Lb.*		*Lb.*		*Lb.*	
26........................	2,305	$-27.70	13,161	$123.61	10,989	$145.98	5,660	$124.30
28........................	2,625	—16.50	10,631	90.46	8,264	96.28	5,979	140.26
Increase due to nitrate	—320	—11.20	2,530	33.15	2,725	49.70	—319	—15.96

Similarly if the results of Plot 36 be subtracted from those of Plot 34, we have the increase secured by adding 160 pounds of nitrate to a treatment of acid phosphate and lime. In this case the tomato crop showed a profit from the nitrate, otherwise the results are substantially in harmony.

Plot	Corn		Cucumbers		Cabbage		Tomatoes	
	Increase	Net profit	Increase	Net profit	Increase	Net profit	Increase	Net profit
	Lb.		*Lb.*		*Lb.*		*Lb.*	
34	1,253	$11.26	3,773	$42.79	7,401	$134.22	3,020	$91.90
36	255	—3.90	781	2.71	3,670	64.40	1,642	48.47
Increase due to nitrate	998	14.16	2,992	40.08	3,731	69.82	1,378	43.43

THE USE OF PHOSPHORUS ALONE

There is no single plot in these experiments where phosphorus is used alone, for Plot 11 has the basic treatment of lime. However, by calculating the increase in yield on this plot the effect of the acid phosphate is virtually secured, for the adjacent check plots were also treated with lime. The only treatment on corn that gives a higher net profit is that on Plot 9 which receives 160 pounds nitrate of soda in addition to 400 pounds of acid phosphate. Tomatoes have given a good yield from this treatment and the net returns are $51.11 per year. Cabbage requires nitrogen, probably more than it requires phosphorus, and while an average net profit of $30.60 has been secured from this treatment in Series A the net profit has been more than doubled by using 160 pounds of nitrate of soda with it. The same is true of cucumbers.

In Series B the addition of acid phosphate to a basic treatment of limestone has given some increase in yield, except with corn, but does not justify the expense (Plots 33 and 36). From a knowledge of the behavior of these plots the authors would be inclined, in view of this discrepancy, to accept the lessons of Series A, Plot 11, as discussed above.

Plots 25 and 28 indicate that considerable increase in yield can be gained with cucumbers and tomatoes by adding 400 pounds of acid phosphate to 16 tons of manure and 1 ton ground limestone, but that the net profits show a loss with cabbage, while corn still shows a loss as a result of the treatment.

POTASH HAS NOT INCREASED YIELDS IN THIS EXPERIMENT

By examining the increases in Plots 8 and 9 it will be seen that the dropping out of 50 pounds of potash has not influenced the crop yield. There is a somewhat better average yield with corn, cucumbers, and tomatoes where the potash is not used. However, this is not to be interpreted as an injurious effect of the material but as a soil difference or natural fluctuation of a few hundred pounds in total yield which is found thruout the experiment. Just how much potash should be used in order to influence production with these crops is not clear from the experiment, but probably not less than that used in Plot 6, or 100 pounds per acre. In time a potash deficiency in this soil may become more apparent.

EFFECT OF LIMESTONE

Lime may be classed by itself when considering fertilizers, for it has other functions than that of furnishing plant food. It is most commonly thought of as merely neutralizing soil acidity but in so doing it provides a more favorable condition for the growth of soil organisms, that are associated with legumes in gathering nitrogen from the air, and for those which aid in the decomposition of organic compounds. There is also a chemical action that converts insoluble forms of potassium and phosphorus into soluble forms. In addition to these, lime has a beneficial mechanical influence on the texture of soils, making heavy, stiff soils more light and friable and binding the sandy soils more closely together.

The effect of ground limestone can best be studied in Series B. The following increases and profits were obtained by the use of 1 ton ground limestone per year without other treatment.

8-YEAR AVERAGE INCREASE AND PROFIT FROM ONE TON GROUND LIMESTONE PER YEAR

	Pounds	Increase	Profits
		Percent	*Dollars*
Sweet corn	787	12.10	10.74
Cucumbers	629	4.84	4.43
Cabbage	3,337	23.83	61.74
Tomatoes	630	10.33	17.05

These figures indicate that cabbage gives the largest gain from lime and that the application of a ton of ground limestone per year is not too much for cabbage on this type of soil. Incidentally, lime is recommended in combating the clubroot disease of cabbage. The profit from the use of 1 ton a year of ground limestone alone on cabbage gives a return of over 1,200 percent on the investment. The profit side of the ledger for the other crops shows that it should not be neglected for them either, since the lowest return (on cucumbers) is almost 100 percent on the investment. In the discussion of the untreated plots on page 128, it will be noticed that there is quite a difference between the yields of the check plots of the two series, those of Series A being higher than those of B. While it is, perhaps, not accurate to say that all of the increase is due to the difference in basic treatment, the difference is at least indicative of the increase that can be expected from two tons of ground limestone, applied every two years, on this type of soil.

The question now arises, Is lime beneficial and profitable when added to other fertilizer treatments? This is answered by the differences between Plots 25 and 24 and between 31 and 30.

8-YEAR AVERAGE INCREASE AND PROFIT FROM TREATMENTS

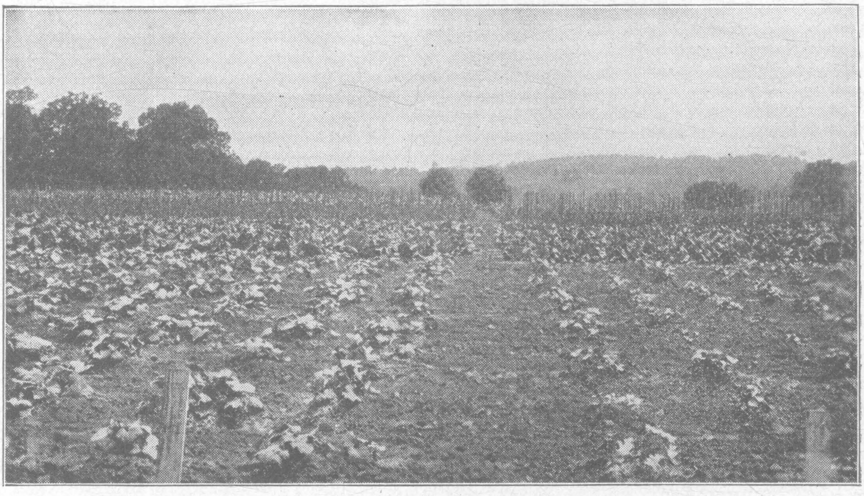
Plot	Treatment	Sweet corn		Cucumbers		Cabbage		Tomatoes	
		Increase	Profit	Increase	Profit	Increase	Profit	Increase	Profit
		Lb.	*Dollars*	*Lb.*	*Dollars*	*Lb.*	*Dollars*	*Lb.*	*Dollars*
25	16 ton manure and 1 ton limestone..........	2,255	—19.90	9,217	73.25	8,369	102.38	5,779	137.26
24	16 ton manure............	2,092	—18.15	7,851	57.77	7,514	90.28	5,236	123.27
	Difference due to 1 ton limestone.....	163	—1.75	1,366	15.48	855	12.10	543	13.99
31	610 lb. 4-10-4 and 1 ton limestone.	1,262	9.94	5,753	70.99	7,780	140.30	2,440	70.10
30	610 lb. 4-10-4..............	1,053	10.76	6,136	81.74	5,581	101.32	2,400	73.70
	Difference due to 1 ton limestone	209	—.82	—383	—10.75	2,199	38.98	—40	—3.60

It will be noted that, altho the limestone gave an increased production on all crops when used with 16 tons of manure, the production was not profitable on sweet corn. Cucumbers gave a much larger increase and profit with manure and limestone than when limestone alone was used, indicating that it is of special value when added to manure for cucumbers. Tomatoes gave the second highest profit, and cabbage third, with sweet corn showing a slight loss. It should be realized that the seemingly small profit on cabbage is almost 250 percent profit on the investment, for the limestone costs only $5 a ton spread on the land.

Only two of the four crops show an increase in production from the addition of ground limestone to 610 pounds of a 4-10-4 chemical fertilizer, thus indicating that it is not a profitable practice. Cabbage is the only one of the crops to give a profit and demonstrates again the need of this crop for lime. The lime seems to be actually harmful to cucumbers for it reduced materially the yield.

This is not the first instance in which the addition of lime to chemical fertilizers has lowered the yield below that obtained from the use of chemical fertilizers alone. The same thing has occurred in a fertilizer experiment on vegetables recently started on the Station grounds at Wooster.

The question that now arises is, Why do some of the crops show an increase and others a decrease in production under the same conditions? The answer seems to lie in the feeding power of the different plants for the tricalcium phosphate that is formed by the excess of lime with acid phosphate. According to Truog[1] the feeding power of plants for raw rock phosphate, which is largely tricalcium phosphate, is dependent upon the calcium oxide intake of the plant. Crops having a high calcium-oxide content have a relatively high feeding power for raw rock phosphate and for those with a low calcium-oxide content the converse is true. Cabbage has a high calcium-oxide content, and ash analyses show that the calcium-oxide content of the plants involved ranges downward in the following order: cabbage, corn, cucumbers, and tomatoes. We would expect them then to show the same range in their feeding power for raw rock phosphate or tricalcium phosphate. Table II shows that cabbage gives the largest increase, sweet corn next and cucumbers instead of tomatoes the least. This agrees rather closely with the calcium oxide range and supports the explanation.



Plot 28, on left, receiving 16 tons manure, 400 pounds acid phosphate and one ton ground limestone. Plot 29 untreated check on right. Note the comparative size of cucumber vines on the treated plot

The recommended practice then is to apply these two materials at different times. Limestone may be applied during the winter or early spring and plowed under and the chemical fertilizer broadcasted before planting without harmful results. In a four-year rotation using these four crops it would be best to apply the lime on the corn and cabbage since these crops make the largest gain under all of the treatments mentioned.

[1]Truog, Emil, Wis. Agr. Exp. Sta. Research Bul. 41.

TABLE I.—Series A, 8-year Average Increase in Yield and the Net Profits for Each Crop, in Descending Order, 1915-1922

Sweet corn				Cucumbers				Cabbage				Tomatoes			
Plot	Increase	Plot	Net profit	Plot	Increase	Plot	Net profit	Plot	Increase	Plot	Net profit	Plot	Increase	Plot	Net profit
No.	*Lb.*	*No.*		*No.*	*Lb.*	*No.*		*No.*	*Lb.*	*No.*		*No.*	*Lb.*	*No.*	
6	884	9	$7.38	2	4,036	9	$45.04	6	4,892	6	$77.24	2	4,153	6	$99.17
9	809	11	5.53	Av. 3, 5	3,711	8	38.53	2	4,847	9	61.61	6	3,422	2	81.37
Av. 3, 5	705	8	2.26	6	3,669	6	34.43	Av. 3, 5	3,589	8	59.47	Av. 3, 5	3,219	9	65.63
8	628	15	1.13	9	3,589	15	24.48	9	3,520	15	40.47	9	2,127	8	54.39
11	477	12	—.08	8	3,256	11	22.99	8	3,489	2	32.94	8	1,848	Av. 3 ,5	52.68
2	473	14	—.47	15	1,952	12	18.58	15	2,263	14	30.63	11	1,575	11	51.11
15	296	6	—2.91	11	1,799	14	14.54	14	1,772	11	30.60	12	185	12	2.14
14	217	Av. 3, 5	—45.89	12	1,529	2	—3.46	11	1,730	12	24.35	15	184	15	1.64
12	213	2	—54.54	14	1,289	Av. 3, 5	—4.32	12	1,435	Av. 3, 5	12.78	14	55	14	—2.88

The following treatments on a basic treatment of 2 tons ground limestone biennially and cover crops:
Plot 2 Shed manure 16 tons, acid phosphate 400 lbs.
3-5 Shed manure 16 tons.
6 Acid phosphate 800 lb., nitrate of soda 320 lb., muriate of potash 100 lb.
8 Acid phosphate 400 lb., nitrate of soda 160 lb., muriate of potash 50 lb.
9 Acid phosphate 400 lb , nitrate of soda 160 lb.
11 Acid phosphate 400 lb.
12 Nitrate of soda 80 lb., sulphate ammonia 65 lb.
14 Nitrate of soda 160 lb. in two applications.
15 Nitrate of soda 160 lb. in one application.

TABLE II.—Series B, 8-year Average Increase in Yield and the Net Profits for Each Crop, in Descending Order, 1915-1922

Sweet corn				Cucumbers				Cabbage				Tomatoes			
Plot	Increase	Plot	Net profit	Plot	Increase	Plot	Net profit	Plot	Increase	Plot	Net profit	Plot	Increase	Plot	Net profit
No.	*Lb.*	*No.*		*No.*	*Lb.*	*No.*		*No.*	*Lb.*	*No.*		*No.*	*Lb.*	*No.*	
28	2,625	34	$11.26	26	13,161	26	$123.61	26	10,989	26	$145.98	28	5,979	28	$140.26
26	2,305	30	10.76	28	10,631	28	90.46	23	9;926	31	140.30	25	5,779	25	137.26
25	2,255	33	10.74	25	9,217	30	81.74	25	8,369	34	134.22	23	5,675	23	128.32
Av. 24, 27	2,092	31	9.94	Av. 24, 27	7,851	25	73.25	28	8,264	23	128.22	26	5,660	26	124.30
23	1,743	36	—3.90	23	7,010	31	70.99	31	7,780	25	102.38	Av. 24, 27	5,236	Av. 24, 27	123.27
31	1,262	28	—16.50	30	6,136	Av. 24, 27	57.77	Av. 24, 27	7,514	30	101.32	34	3,020	34	91.90
34	1,253	Av. 24, 27	—18.15	31	5,753	34	42.79	34	7,401	28	96.28	31	2,440	30	73.70
30	1,053	25	—19.90	34	3,773	23	34.85	30	5,581	Av. 24, 27	90.28	30	2,400	31	70.10
33	787	26	—27.70	21	845	33	4.43	36	3,670	36	64.40	36	1,642	36	48.47
36	255	23	—35.44	36	781	36	2.71	33	3,337	33	61.74	33	630	33	17.05
21	—330	21	—73.80	33	629	21	—54.53	21	—2,570	21	—118.60	21	—1,092	21	—105.42

The following are the treatments given on a basic treatment of cover crops only.

Plot 21 Straw mulch 7 T. per acre.
23 Manure 16 T., acid phosphate 400, nitrate of soda 160, muriate of potash 50.
24 and 27 Manure 16 T.
25 Manure 16 T., ground limestone 1 T.
26 Manure 16 T., acid phosphate 400, nitrate of soda 160, limestone 1 T.
28 Manure 16 T., acid phosphate 400, limestone 1 T.
30 Acid phosphate, nitrate of soda 160, muriate of potash 50.
31 Acid phosphate 400, nitrate of soda 160 lb., muriate of potash 50 lb., limestone 1 T.
33 Ground limestone 1 T.
34 Acid phosphate 400 lb., nitrate of soda 160 lb., limestone 1 T.
36 Acid phosphate 400 lb., ground limestone 1 T.

TABLE III.—Series A,* 8-year Average Annual Yield and Increase in Pounds Per Acre and Increase in Percent, 1915-1922

Plot	Sweet corn			Cucumbers			Cabbage			Tomatoes		
	Yield	Increase	Increase	Yield	Increase	Increase	Yield	Increase	Increase	Yield	Increase	Increase
	Lb.	*Lb.*	*Percent*	*Lb.*	*Lb.*	*Percent*	*Lb.*	*Lb.*	*Percent*	*Lb.*	*Lb.*	*Percent*
1	7,520	....	....	15,588	....	....	17,140	....	....	10,251	....	....
2	7,962	473	6.31	19,562	4,036	25.99	22,097	4,847	28.09	14,422	4,153	40.44
3	7,960	502	6.73	18,830	3,366	21.76	21,260	3,900	22.46	13,756	3,470	33.73
4	7,427	....	....	15,402	....	....	17,470	....	....	10,304	....	....
5	8,245	909	12.39	19,848	4,057	29.69	20,640	3,278	18.88	13,182	2,969	29.07
6	8,130	884	12.19	19,848	3,669	22.67	22,145	4,892	28.35	13,544	3,422	33.80
7	7,155	....	....	16,568	....	....	17,145	....	....	10,031	....	....
8	7,827	628	8.72	19,641	3,256	19.87	20,467	3,489	20.55	11,869	1,848	18.44
9	8,052	809	11.16	19,792	3,589	22.15	20,332	3,520	20.93	12,137	2,127	21.24
10	7,287	....	....	16,020	....	....	16,645	....	....	10,000	....	....
11	7,777	477	6.53	17,774	1,799	11.26	18,190	1,730	10.51	11,350	1,575	16.11
12	7,527	213	2.91	17,459	1,529	9.59	17,710	1,435	8.81	9,736	185	1.93
13	7,327	....	....	15,885	....	....	16,090	....	....	9,326	....	....
14	7,517	217	2.97	16,489	1,289	8.48	17,375	1,772	11.35	9,147	155	.60
15	7,570	296	4.06	16,466	1,952	13.44	17,380	2,263	14.96	9,042	84	2.07
16	7,247	....	....	13,829	....	....	14,630	....	....	8,624	....	....
Av. checks	7,327	....	....	15,549	....	....	16,520	....	....	9,756	....	....

*Basic treatment: cover crops and 2 tons ground limestone every second year.

TABLE IV.—Series A,* 8-year Average Annual Value Per Acre of Truck Crops, Value of Increase, Cost of Treatment, and Profit or loss (—) From Treatment, 1915-1922

Plot	Sweet corn			Cucumbers			Cabbage			Tomatoes			Cost of treatment
	Yield	Increase	Profit	Yield	Increase	Profit	Yield	Increase	Profit	Yield	Increase	Profit	
1	$150.40	....	....	$233.82	....	....	$342.80	....	....	$358.78	....	....	....
2	159.24	$ 9.46	$—54.54	293.43	$60.54	$ —3.46	441.94	$96.94	$32.94	504.77	$145.37	$81.37	$64.00
3	159.20	10.04	—49.96	282.45	50.49	—9.51	425.20	78.00	18.00	481.46	121.44	61.44	60.00
4	148.54	....	....	231.03	....	....	349.40	....	....	360.64	....	....	....
5	164.90	18.17	—41.83	297.72	60.86	.86	412.80	65.56	5.56	461.37	103.92	43.92	60.00
6	162.60	17.69	—2.91	297.72	55.03	34.43	442.90	97.84	77.24	474.04	119.77	99.17	20.60
7	143.10	....	....	248.52	....	....	342.90	....	....	351.08	....	....	....
8	156.54	12.56	2.26	294.61	48.83	38.53	409.34	69.77	59.47	415.41	64.69	54.39	10.30
9	161.04	16.18	7.38	296.88	53.84	45.04	406.64	70.41	61.61	424.79	74.43	65.63	8.80
10	145.74	....	....	240.30	....	....	332.90	....	....	350.00	....	....	....
11	155.54	6.53	5.53	266.61	26.99	22.99	363.80	34.60	30.60	397.25	55.11	51.11	4.00
12	150.54	4.27	—.08	261.88	22.93	18.58	354.20	28.70	24.35	340.76	6.49	2.14	4.35
13	146.54	....	....	238.27	....	....	321.80	....	....	326.41	....	....	....
14	150.34	4.33	—.47	247.33	19.34	14.54	347.50	35 43	30.63	320.14	1.92	—2.88	4.80
15	151.40	5.93	1.13	246.99	29.28	24.48	347.60	45.27	40.47	316.47	6.44	1.64	4.80
16	144.94	....	....	207.43	....	....	292.60	....	....	301.84	....	....	....

*Basic treatment: cover crops annually and 2 tons of ground limestone every second year.

TABLE V.—Series B,* 8-year Average Annual Yield and Increase in Pounds Per Acre and Increase in Percent, 1915-1922

Plot	Sweet corn			Cucumbers			Cabbage			Tomatoes		
	Yield	Increase	Increase	Yield	Increase	Increase	Yield	Increase	Increase	Yield	Increase	Increase
No.	*Lb.*	*Lb.*	*Percent*	*Lb.*	*Lb.*	*Percent*	*Lb.*	*Lb.*	*Percent*	*Lb.*	*Lb.*	*Percent*
21	5,675	—330	—5.49	11,859	845	7.67	12,435	—2,570	—17.12	6,635	—1,092	—14.13
22	6,005	....	....	11,014	....	....	15,005	....	....	7,727	....	....
23	8,250	1,743	26.78	20,035	7,010	53.81	25,117	9,926	65.34	13,490	5,675	72.61
24	8,517	2,010	30.88	20,017	6,992	53.69	23,065	7,874	51.83	13,079	5,264	67.35
25	8,762	2,255	34.65	22,242	9,217	70.76	23,560	8,369	55.09	13,594	5,779	73.94
26	8,812	2,305	35.42	26,186	13,161	101.04	26,180	10,989	72.33	13,475	5,660	72.42
27	8,682	2,175	33.42	21,736	8,711	66.87	22,345	7,154	47.09	13,024	5,209	66.65
28	9,132	2,625	40.34	23,656	10,631	81.61	23,455	8,264	54.40	13,794	5,979	76.50
29	7,010	....	....	15,036	....	....	15,377	....	....	7,904	....	....
30	7,960	1,053	15.24	20,878	6,136	41.63	20,560	5,581	37.25	9,695	2,400	32.89
31	8,065	1,262	18.55	20,194	5,753	39.83	22,360	7,780	53.36	9,126	2,440	36.49
32	6,700	....	....	14,144	....	....	14,182	....	....	6,077	....	....
33	7,290	787	12.10	13,617	629	4.84	17,335	3,337	23.83	6,725	630	10.33
34	7,557	1,253	19.87	15,604	3,773	31.89	21,215	7,401	53.57	9,134	3,020	49.39
35	6,107	....	....	10,675	....	....	13,630	....	....	6,132	....	....
36	6,362	255	4.17	11,456	781	6.81	17,300	3,670	26.92	7,774	1,642	26.77
Av. checks	6,455	....	....	12,715	....	....	14,548	....	....	6,960	....	....

*Basic treatment: cover crop only.

TABLE VI.—Series B,* 8-year Average Annual Value Per Acre of Truck Crops, Value of Increase, Cost of Treatment, and Profit, 1915-1922

Plot No.	Sweet corn			Cucumbers			Cabbage			Tomatoes			Cost of treatment per year
	Yield	Increase	Profit	Yield	Increase	Profit	Yield	Increase	Profit	Yield	Increase	Profit	
21	$113.50	$—6.60	$—73.80	$177.88	$ 12.67	$—54.53	$248.70	$—51.40	$—118.60	$232.22	$—38.22	$—105.42	$67.20
22	120.10	....	....	165.21	....	....	300.10	....	....	270.44	....	....	....
23	165.00	34.86	—35.44	300.52	105.15	34.85	502.34	198.52	128.22	472.15	198.62	128.32	70.30
24	170.34	40.20	—19.80	300.25	104.88	44.88	461.30	157.48	97.48	457.76	184.24	124.24	60.00
25	175.24	45.10	—19.90	333.63	138.25	73.25	471.20	167.38	102.38	475.79	202.26	137.26	65.00
26	176.24	46.10	—27.70	392.79	197.21	123.61	523.60	219.78	145.98	471.62	198.10	124.30	73.80
27	173.64	43.50	—16.50	326.04	130.66	70.66	446.90	143.08	83.08	455.84	182.31	122.31	60.00
28	182.64	52.50	—16.50	354.84	159.46	90.46	449.10	165.28	96.28	482.79	209.26	140.26	69.00
29	140.20	....	....	225.54	....	....	307.54	....	....	276.64	....	....	....
30	159.20	21.06	10.76	313.12	92.04	81.74	411.20	111.62	101.32	339.32	84.00	73.70	10.30
31	161.30	25.24	9.94	302.91	86.29	70.99	447.20	155.60	140.30	319.41	85.40	70.10	15.30
32	134.00	....	....	212.16	....	....	283.64	....	....	212.69	....	....	....
33	145.80	15.74	10.74	204.25	9.43	4.43	346.70	66.74	61.74	235.37	22.05	17.05	5.00
34	151.14	25.06	11.26	234.06	56.59	42.79	424.30	148.02	134.22	319.69	105.70	91.90	13.80
35	122.44	....	....	160.12	....	....	272.60	....	....	214.62	....	....	....
36	127.24	5.10	—3.90	171.84	11.71	2.71	346.00	73.40	64.40	272.09	57.47	48.47	9.00

*Basic treatment: cover crops only.

SUMMARY AND DEDUCTIONS

The bulletin reports the results for a period of 8 years, of two series of experiments dealing with the fertilization, manuring, and liming of truck crops. The crops involved in this four-year rotation are sweet corn, cucumbers, cabbage, and tomatoes.

The farm on which this work has been conducted is a part of the Washington County Experiment Farm. It is situated within the Marietta trucking district, where vegetable crops for the early market are produced.

The average yield of this land without any treatment, except that supplied by the green manures, is as follows: sweet corn (ears in the husk), 3.2 tons per acre; cucumbers, 6.6 tons; cabbage, 7.5 tons; and tomatoes 3.3 tons per acre, as indicated in Series B where no lime is applied to the control plots. (See p. 129).

It is clearly shown that the four crops here considered often respond differently to a given treatment, and that fertilizers, manures, and lime should be applied with a view to the crop to be grown rather than as a basic treatment for all vegetable crops.

In a summarized statement it is not possible to directly compare the results of the two experiments treated in this bulletin because of the difference in the basic treatments and in the method of figuring the increases, therefore, the results of Series A and Series B are catalogued separately. The increases in yield are discussed first, and the increases in profits second under each crop.

Ground limestone alone has been profitable on all crops, and on cabbage has returned a profit of over 1,200 percent on the investment.

When used in connection with 16 tons of manure, ground limestone has been profitable on all crops except sweet corn and especially profitable on cucumbers.

When added to 610 pounds of a 4-10-4 chemical fertilizer, 1 ton of ground limestone was profitable only on cabbage. (See possible explanation on page 140).

Since limestone has been so beneficial on most of the treatments on cabbage and sweet corn it is recommended that ground limestone be applied to the land on which these crops are to be grown, several months previous to the application of acid phosphate in chemical fertilizers.

The treatment that gave the largest profit on the four crops in this rotation was the one consisting of 16 tons of manure, 400 pounds of acid phosphate, 160 pounds of nitrate of soda and 1 ton of ground limestone. The complete fertilizer (610 pounds 4-10-4) and limestone gave the largest profits on all four crops when no manure was used.

SERIES A

In Series A a basic treatment of 2 tons of ground limestone biennially and cover crop of cowpeas and rye was given all plots. (See schedule of treatments page 127 and Tables I, III, and IV).

The treatment of 800 pounds acid phosphate, 320 pounds of nitrate of soda, and 100 pounds muriate of potash (1,220 pounds 4-10-4), gave the largest increase on sweet corn.

But this treatment was not the most profitable with this particular crop because of the relatively high cost of the treatment in comparison with the value of the increase. The treatment returning the largest profit was 400 pounds of acid phosphate and 160 pounds of nitrate of soda.

For cucumbers, 16 tons of manure and 400 pounds of acid phosphate gave the largest increase in yield, but the high cost of the manure made such a treatment unprofitable. An application of 1,220 pounds of a 4-10-4 mixture gave the largest profit with this crop.

On cabbage, 1,220 pounds of the 4-10-4 gave the largest yields and likewise the greatest profits, showing that this amount was not too large for that crop.

The combination of 16 tons of manure and 400 pounds of acid phosphate was most effective in increasing the yield of tomatoes. The 1,220 pounds of 4-10-4 is more profitable however than the phosphated manure and also more profitable than 610 pounds of the same formula, again demonstrating the profitableness of the larger application of chemical fertilizers for cabbage and tomatoes.

GENERAL DEDUCTIONS FROM SERIES A

It is evident that the production from this soil can be maintained by the use of chemical fertilizers, ground limestone, and cover crops; for more than twice as much nitrogen and potash and about half as much phosphoric acid are being supplied in the manure as in the largest chemical treatment, and yet the yield is nearly equal in many cases. (See page 134).

Furthermore, the net returns from the use of the chemicals are nearly double, in Series A, due to the cost of the manurial treatments. It is recognized that the organic supply should be maintained in the soil by cover crops, or by manures when they can be laid on the field at less than $2 a ton. The relatively high production and the low cost of the increases from rather moderate applications of chemical fertilizers, are among the most important features of this work to date.

An application of 1,220 pounds of a 4-10-4 mixture was more profitable than 610 pounds of the same mixture with cabbage and tomatoes but not on corn and cucumbers.

Manure has greatly increased the yield of all crops but the increases have only been profitable on cabbage and tomatoes when used in connection with ground limestone and cover crops at the rate of 16 tons per acre and charged at $3.75 per ton. The profits however are not as large as those from the complete fertilizer treatments.

The addition of 400 pounds of acid phosphate to 16 tons of manure increased the yield and profits on every crop except sweet corn.

Acid phosphate applied at the rate of 400 pounds per acre gave profitable increases on all crops.

The addition of 50 pounds of muriate of potash to 400 pounds acid phosphate and 160 pounds nitrate of soda was not a profitable practice on this soil with these crops. It is possible that this amount is not large enough to make a perceptible difference.

Nitrate of soda at the rate of 160 pounds was profitable on all crops but only slightly so on sweet corn and tomatoes. This amount of nitrate of soda in one application gave larger increases and more profit on all the crops than the same amount of nitrate applied in two applications.

Nitrogen from nitrate of soda gave larger increases and profits on all crops except tomatoes than where one-half of the nitrogen was derived from ammonium sulphate.

While it is emphasized in this discussion that the vegetable crops respond differently to similar treatments, yet the treatment that gave the largest profits from the four crops in this series was 1,220 pounds of the 4-10-4 mixture (Plot 6).

SERIES B

A cover crop of cowpeas and rye constituted the basic treatment of Series B. No ground limestone was used on the check plots so a comparison with those of Series A is precluded. The largest application of minerals is 610 pounds of a 4-10-4 and 1 ton ground limestone. (See schedule of treatments page 127 and Tables II, V, and VI).

In this series the treatment with manure, acid phosphate, and limestone gave the largest increase in yield on sweet corn. Where no manure was used a treatment of 610 pounds of a 4-10-4 mixture and limestone gave the largest increase. None of the treatments containing manure was profitable on sweet corn. The most profitable treatment was 400 pounds acid phosphate, 160 pounds nitrate of soda, and 1 ton ground limestone.

On cucumbers, manure, acid phosphate, nitrate of soda, and limestone gave the largest increase. When no manure was used the 610 pounds of complete fertilizer gave the greatest increase. These treatments were likewise most profitable. The treatment containing the manure was more profitable than the complete fertilizer without manure. This does not quite parallel the findings in Series A, but there is no direct comparison because no plot here receives 1,220 pounds of complete fertilizer, and in Series A the manurial treatment is not reenforced with nitrate of soda, which is conducive to high yields of cucumbers.

The treatment of manure, acid phosphate, nitrate of soda, and limestone on cabbage gave the largest increase in yield and profit. Where no manure was used, the complete fertilizer with limestone gave the largest increase and second of all the treatments in financial return.

For tomatoes, manure, acid phosphate, and limestone increased the yield most. Of the straight chemical treatments, 400 pounds of acid phosphate, 160 pounds of nitrate of soda, and 1 ton ground limestone gave the largest increase.

Manure is especially profitable on tomatoes for all of the manurial treatments were more profitable than the chemical treatments. The treatment—manure, acid phosphate, and ground limestone—that gave the largest increase in yield, likewise returned the largest profit. Of the chemical fertilizers, acid phoshate, nitrate of soda, and limestone gave the greatest profit.

GENERAL DEDUCTIONS FROM SERIES B

The use of fresh straw mulch was decidedly unprofitable under the conditions of this work. The plants had a yellowish appearance, indicating a low nitrate supply in this soil.

The largest yields were obtained from the treatments of manure or manure with chemicals altho these treatments were not in all cases the most profitable.

Manure applications of 16 tons per acre at $3.75 per ton were profitable on all crops, except sweet corn, where no limestone was used.

Under the conditions of this experiment the following chemicals have been profitable when used in addition to 16 tons of manure:

1. 1 ton ground limestone for all crops except sweet corn.
2. 1 ton ground limestone and 400 pounds of acid phosphate for all crops except sweet corn.
3. 1 ton ground limestone, 400 pounds of acid phosphate, and 160 pounds of nitrate of soda on all crops except sweet corn, but only slightly profitable on tomatoes.
4. 610 pounds of 4-10-4 on cabbage and slightly profitable on tomatoes.

Where manure is available, supplementing it with ground limestone, acid phosphate, and nitrate of soda for all crops except sweet corn is justified.

Manure is of most value for cucumbers and tomatoes and when it is impossible to cover all the land each year it should be applied to the land on which these crops are to be grown.

An application of 610 pounds of 4-10-4 was more profitable than 16 tons of manure on all crops except tomatoes. This application, with 1 ton of limestone was more profitable than 16 tons of manure plus 1 ton of limestone on sweet corn and cabbage and almost equal to it on cucumbers.

Nitrate of soda was profitable on all crops when added to 400 pounds of acid phosphate and a ton of ground limestone and was still profitable on all crops except tomatoes when used with 16 tons of manure and these amounts of acid phosphate and ground limestone.